Ministry of Higher Education
& Scientific Research
Al Muthanna University
College of Veterinary Medicine
Division of Public Health

Subject: Genetics

Grade: 2

Lecture : 6

❖ DNA transcription

Introduction

What makes death cap mushrooms deadly? These mushrooms get their lethal effects by producing one specific toxin, which attaches to a crucial enzyme in the human body: RNA polymerase.

RNA polymerase is crucial because it carries out **transcription**, the process of copying DNA (deoxyribonucleic acid, the genetic material) into RNA (ribonucleic acid, a similar but more short-lived molecule).

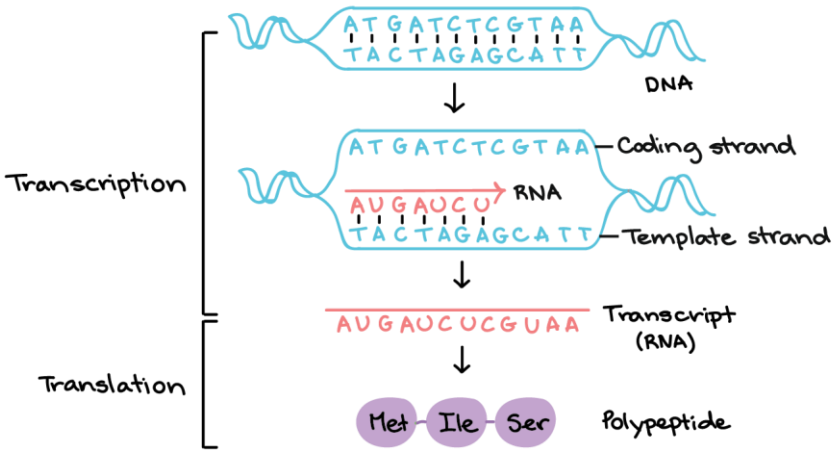
Transcription is an essential step in using the information from genes in our DNA to make proteins. Proteins are the key molecules that give cells structure and keep them running. Blocking transcription with mushroom toxin causes liver failure and death, because no new RNAs—and thus, no new proteins—can be made.^22squared

Transcription is essential to life, and understanding how it works is important to human health. Let's take a closer look at what happens during transcription.

Transcription overview

Transcription is the first step of gene expression. During this process, the DNA sequence of a gene is copied into RNA.

Before transcription can take place, the DNA double helix must unwind near the gene that is getting transcribed. The region of opened-up DNA is called a **transcription bubble**.



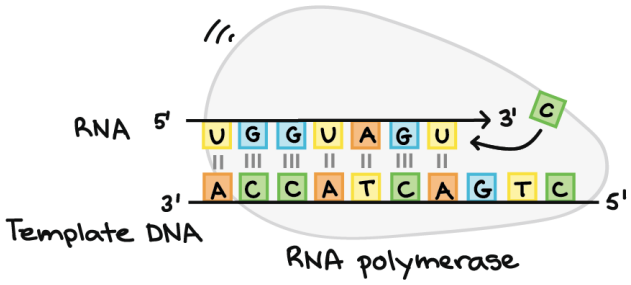
Transcription uses one of the two exposed DNA strands as a template; this strand is called the **template strand**. The RNA product is complementary to the template strand and is almost identical to the other DNA strand, called the **nontemplate** (or **coding**) **strand**. However, there is one important difference: in the newly made RNA, all of the T nucleotides are replaced with U nucleotides.

The site on the DNA from which the first RNA nucleotide is transcribed is called the +1+1plus, 1 site, or the **initiation site**. Nucleotides that come before the initiation site are given negative numbers and said to be **upstream**. Nucleotides that come after the initiation site are marked with positive numbers and said to be **downstream**.

If the gene that's transcribed encodes a protein (which many genes do), the RNA molecule will be read to make a protein in a process called translation.

RNA polymerase

RNA polymerases are enzymes that transcribe DNA into RNA. Using a DNA template, RNA polymerase builds a new RNA molecule through base pairing. For instance, if there is a G in the DNA template, RNA polymerase will add a C to the new, growing RNA strand.



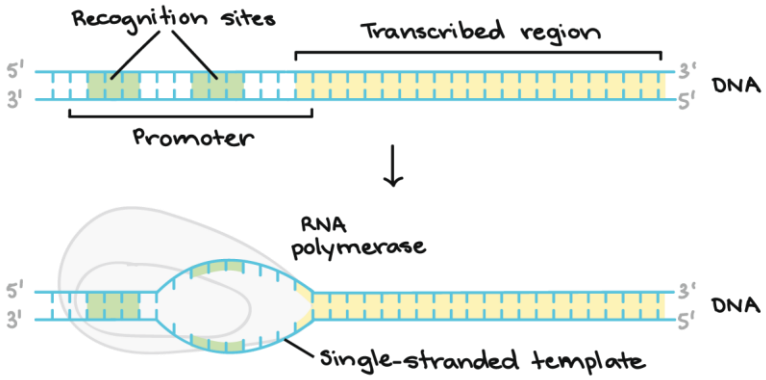
RNA polymerase always builds a new RNA strand in the **5' to 3'** direction. That is, it can only add RNA nucleotides (A, U, C, or G) to the 3' end of the strand.

[What do 5' and 3' mean?]

RNA polymerases are large enzymes with multiple subunits, even in simple organisms like bacteria. Humans and other eukaryotes have three different kinds of RNA polymerase: I, II, and III. Each one specializes in transcribing certain classes of genes. Plants have an additional two kinds of RNA polymerase, IV and V, which are involved in the synthesis of certain small RNAs.

Transcription initiation

To begin transcribing a gene, RNA polymerase binds to the DNA of the gene at a region called the **promoter**. Basically, the promoter tells the polymerase where to "sit down" on the DNA and begin transcribing.



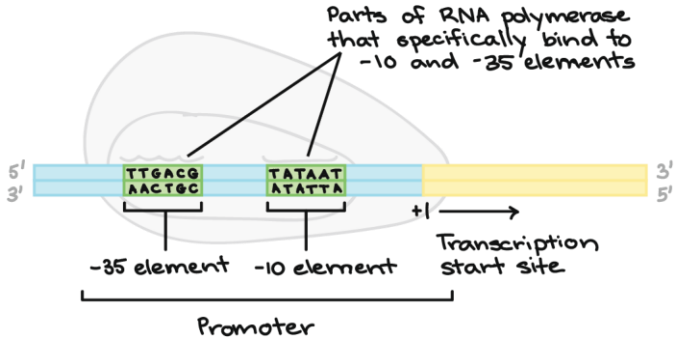
Each gene (or, in bacteria, each group of genes transcribed together) has its own promoter. A promoter contains DNA sequences that let RNA polymerase or its helper proteins attach to the DNA. Once the transcription bubble has formed, the polymerase can start transcribing.

Promoters in bacteria

To get a better sense of how a promoter works, let's look an example from bacteria. A typical bacterial promoter contains two important DNA sequences, the -**101010** and -**353535 elements**.

RNA polymerase recognizes and binds directly to these sequences. The sequences position the polymerase in the right spot to start transcribing a target gene, and they also make sure it's pointing in the right direction.

Once the RNA polymerase has bound, it can open up the DNA and get to work. DNA opening occurs at the -101010 element, where the strands are easy to separate due to the many As and Ts (which bind to each other using just two hydrogen bonds, rather than the three hydrogen bonds of Gs and Cs).

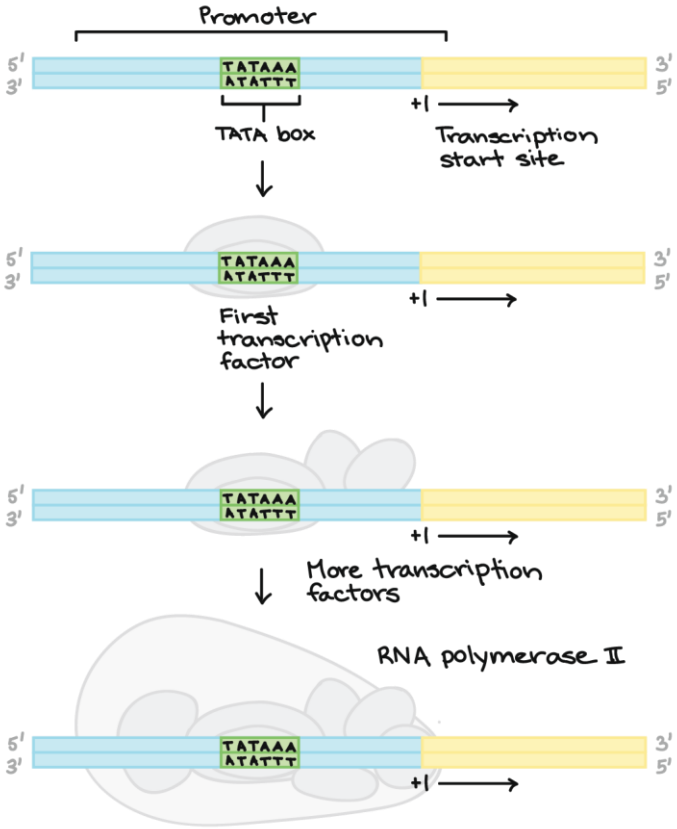


The -101010 and the -353535 elements get their names because they come 353535 and 101010 nucleotides before the initiation site (+1+1plus, 1 in the DNA). The minus signs just mean that they are before, not after, the initiation site.

Promoters in humans

In eukaryotes like humans, the main RNA polymerase in your cells does not attach directly to promoters like bacterial RNA polymerase. Instead, helper proteins called **basal** (**general**) **transcription factors** bind to the promoter first, helping the RNA polymerase in your cells get a foothold on the DNA.

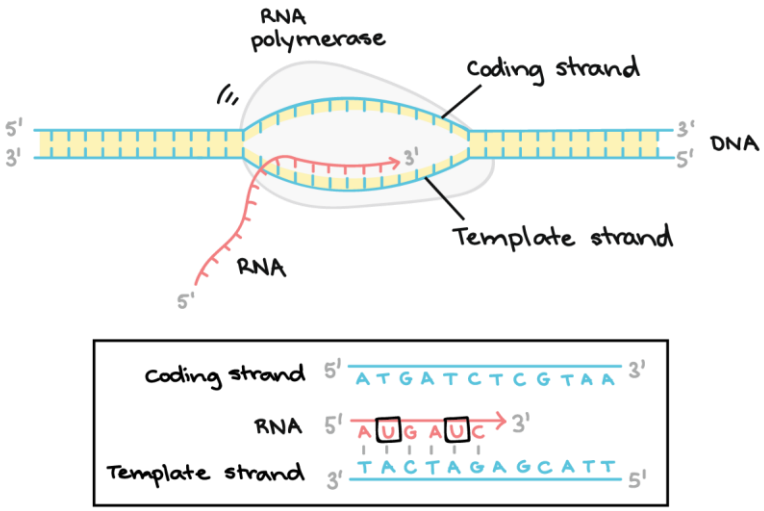
Many eukaryotic promoters have a sequence called a **TATA box**. The TATA box plays a role much like that of the -101010 element in bacteria. It's recognized by one of the general transcription factors, allowing other transcription factors and eventually RNA polymerase to bind. It also contains lots of As and Ts, which make it easy to pull the strands of DNA apart.



Elongation

Once RNA polymerase is in position at the promoter, the next step of transcription—elongation—can begin. Basically, e**long**ation is the stage when the RNA strand gets **long**er, thanks to the addition of new nucleotides.

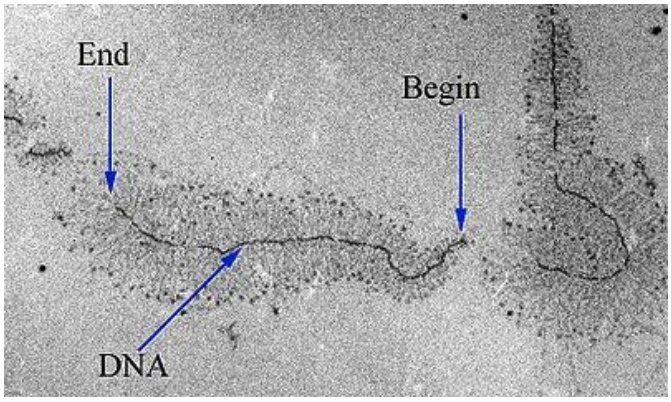
During elongation, RNA polymerase "walks" along one strand of DNA, known as the **template strand**, in the 3' to 5' direction. For each nucleotide in the template, RNA polymerase adds a matching (complementary) RNA nucleotide to the 3' end of the RNA strand.



The RNA transcript is nearly identical to the **non-template**, or **coding**, strand of DNA. However, RNA strands have the base uracil (U) in place of thymine (T), as well as a slightly different sugar in the nucleotide. So, as we can see in the diagram above, each T of the coding strand is replaced with a U in the RNA transcript.

[See a diagram of the bases]

The picture below shows DNA being transcribed by many RNA polymerases at the same time, each with an RNA "tail" trailing behind it. The polymerases near the start of the gene have short RNA tails, which get longer and longer as the polymerase transcribes more of the gene.



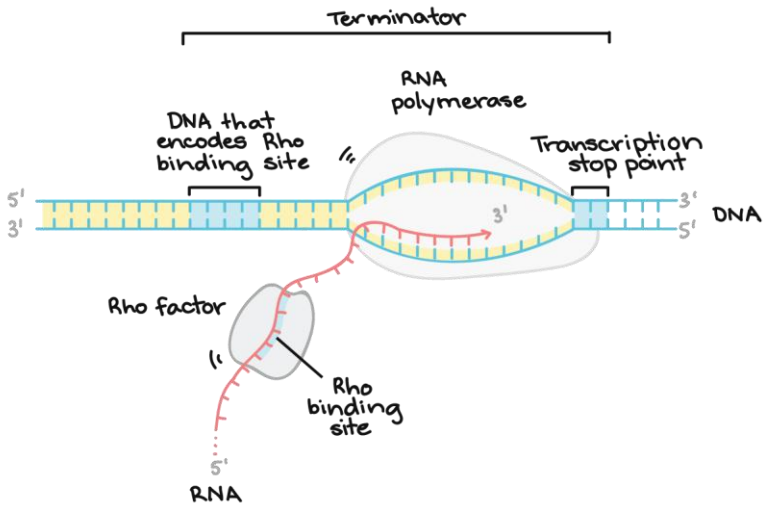
Transcription termination

RNA polymerase will keep transcribing until it gets signals to stop. The process of ending transcription is called **termination**, and it happens once the polymerase transcribes a sequence of DNA known as a **terminator**.

Termination in bacteria

There are two major termination strategies found in bacteria: Rho-dependent and Rho-independent.

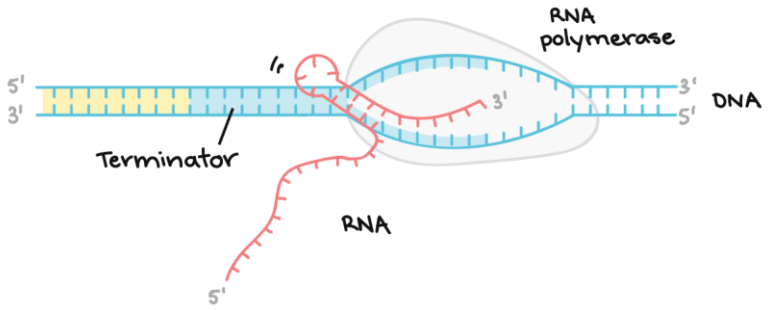
In **Rho-dependent termination**, the RNA contains a binding site for a protein called Rho factor. Rho factor binds to this sequence and starts "climbing" up the transcript towards RNA polymerase.



When it catches up with the polymerase at the transcription bubble, Rho pulls the RNA transcript and the template DNA strand apart, releasing the RNA molecule and ending transcription. Another sequence found later in the DNA, called the transcription stop point, causes RNA polymerase to pause and thus helps Rho catch up.^44start superscript, 4, end superscript

Rho-independent termination depends on specific sequences in the DNA template strand. As the RNA polymerase approaches the end of the gene being transcribed, it hits a region rich in C and G nucleotides. The RNA transcribed from

this region folds back on itself, and the complementary C and G nucleotides bind together. The result is a stable hairpin that causes the polymerase to stall.



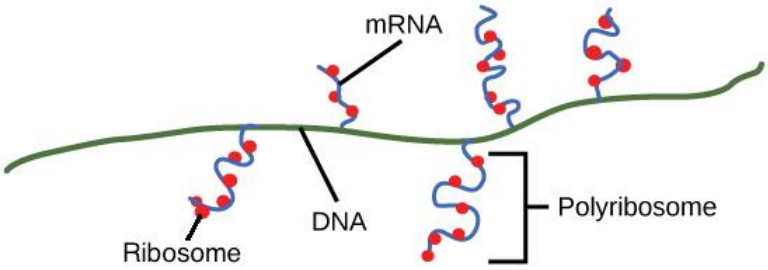
In a terminator, the hairpin is followed by a stretch of U nucleotides in the RNA, which match up with A nucleotides in the template DNA. The complementary U-A region of the RNA transcript forms only a weak interaction with the template DNA. This, coupled with the stalled polymerase, produces enough instability for the enzyme to fall off and liberate the new RNA transcript.

[Transcription termination in eukaryotes]

What happens to the RNA transcript?

After termination, transcription is finished. An RNA transcript that is ready to be used in translation is called a **messenger RNA** (**mRNA**). In bacteria, RNA transcripts are ready to be translated right after transcription. In fact, they're actually ready a little sooner than that: translation may start while transcription is still going on!

In the diagram below, mRNAs are being transcribed from several different genes. Although transcription is still in progress, ribosomes have attached each mRNA and begun to translate it into protein. When an mRNA is being translated by multiple ribosomes, the mRNA and ribosomes together are said to form a **polyribosome**.



Why can transcription and translation happen simultaneously for an mRNA in bacteria? One reason is that these processes occur in the same 5' to 3' direction. That means one can follow or "chase" another that's still occurring. Also, in bacteria, there are no internal membrane compartments to separate transcription from translation.

The picture is different in the cells of humans and other eukaryotes. That's because transcription happens in the nucleus of human cells, while translation happens in the cytosol. Also, in eukaryotes, RNA molecules need to go through special processing steps before translation. That means translation can't start until transcription and RNA processing are fully finished

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